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Algorithm for Detection of *Aonidiella aurantii* in *Citrus x* tangelo Fruits using DIP Techniques

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Abstract

Objectives: To develop an algorithm to classify the fruit damage caused by the *Aonidiella aurantii* pest in a Citrus x tangelo crop. With this detection and prediction is intended to provide a tool for estimation of pesticide application doses on the affected plants. **Methods/Statistical Analysis:** A system based on digital image processing was implemented, to recognize the fruits that pass through a conveyor belt, thus to select the quality fruits. As of Digital techniques as 2D Fourier transform, for calculate the intensity changes on the image, digital filtering, Circle Hough transform as method to detect circular contours and HSB color model related to represent the colors based on three parameters: Hue, Saturation and Brightness. **Findings:** The algorithm was capable to identify and classify Citrus x Tangelo fruits, using as parameter the recognized affected surface. After the image segmentation, a new mask was applied to recognize the free *A. aurantii* area of the fruit, as of second histogram information, was possible to obtain the healthy area of the fruit. One of the factors to obtain a feasible identification of the health areas on the fruits was the quantity and quality was the light in the work environment, due to a degradation of these factors could lead to a bad interpretation of the data when reflections or shadows are present. **Application/Improvements:** The main contribution of this system is the implementation of artificial vision methods for detecting affected areas on the surface of the fruit and determines its quality in order to accomplish the task of fruit selection. Also this work contributes to the development of agro industry, proposing new non-invasive methodologies to improve the production process in the agricultural sector in Colombia.

Keywords: *Aonidiella aurantii*, Artificial Vision, Detection Algorithm, DIP Techniques, Orange Crops

1. Introduction

The orange is a fruit that is generally cultivated in temperate climates, making it easy to be attacked by pests such as whitefly, trips, mites, red lice California, among others[1]. Such kinds of pest traditionally are controlled by using different types of fungicides, which are often harmful to human health when are excessively applied without a parameter support to help the agriculturist to determine the appropriate dosage according to the growth of the pest.

Attempts to mitigate the effects of insects on crops have been worked in the application of chemicals, optimization of the same crops using genetic engineering or the use of external agents[2,3]. Also, studies based on heuristic methods have provided association in technological terms in relation to its application in agro-industry[4].

Accordingly, an important method for detecting pest damage in crops is the use of elements and technologically valid systems, such as the implementation of image processing[5] or chemical analysis, which provide data on the composition and appearance of the fruit to determine the "grow" and "health" state in which it is classified. For extraction systems through images, is used the physiognomy of the fruit as the analysis basis avoiding destructive manipulations to the fruits.

Among the important works that have used technological advances in terms of improving the productivity of agricultural crops as well as quality control carried out on these, is the one presented in[6] which make use of multispectral technology to make the selection of citrus from the condition of the shell, or the estimation of the volume and mass of citrus fruits such as lime, lemon, orange and tangerine as shown in[7], which also is achieved a confidence interval equal to 95%.

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In[8] is implemented a multivariable analysis of images to detect damage on citrus peel. In the work presented in[9], the technological development to support improved agricultural production processes is explored to develop a simulator of the fly which attacks fruit, in order to support biosecurity in crops.

Likewise, methods and large-scale systems such as the one presented in[10] allow remote monitoring of crops, taking into account technological limitations that exist for large crops. This would mean improvements in productivity in large scale terrains where manual monitoring is demanded and not affordable.

The main objective of the work presented in this paper is the description of development of an algorithm to classification of the fruit damage caused by the *Aonidiella aurantii* pest in a Citrus x tangelo crop. With this detection and prediction is intended to provide a tool for estimation of pesticide application doses on the affected plants.

2. Materials and Methods

2.1 Quality Control

The quality control system performs the recognition and selection tasks of the fruits through the image processing algorithm. Figure 1 depicts the main elements used for the selective process.

Figure 1 shows a supply container in the left side, which delivers the fruit to the conveyor belt. At the sides of the conveyor are located and aligned a pair of cameras for the photographic record of the fruit surface. The acquired images through the cameras have a maximum dimension of 1456 x 2592 pixels, which is sufficient to estimate the differences in the surface of the fruit. At the end of the band is located pneumatic actuator which discards or allows the pass of the fruits depending on the registered conditions and evaluated by the algorithm.

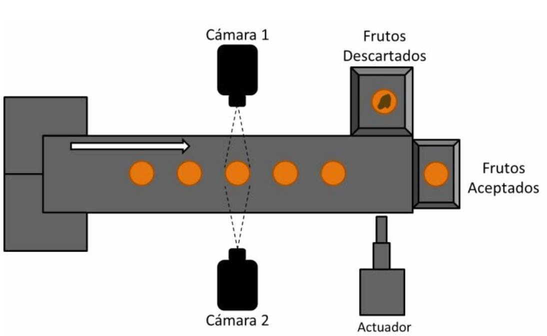

Figure 1. System representation.

2.2 2D-Fourier Transform

The frequency concept in digital image processing is used to refer to the spatial frequency of the image. Although the frequency is a term that is often associated with the temporal variation of a signal, this concept applied to image processing, refers to the estimation of the intensity among the pixels that compose it and which also depends on the spatial coordinates. Image areas where intensity changes are not abrupt have low spatial frequencies, and those areas with edges and sharp details are comprised of high spatial frequencies. The Fourier transform of an image is the one of the most widely used methods to estimate spectral data from images[11] a 2D sliding DFT (2D SDFT. This method must be performed in two dimensions, calculating intensity changes present in both rows and columns of pixels that form the image. Equation 1 shows mathematically this concept.

$$F(u,v) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)e^{-j2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)} \quad (1)$$

Where,
M = Number of rows.
N = Number of columns.
u, v = Actual coefficient index.
x, y = Coordinate data of the pixel for calculation.

Figure 2 depicts a Citrus x Tangelo fruit in the RGB color space, its representation in gray scale and the spatial frequencies of the image.

The purpose of applying the Fourier transform is to condition the images to perform filtering process, in order to reduce the number of operations from the convolution task on the time domain to multiplications in the frequency representations[12].

Figure 2. RGB, gray scale and frequency representation of a C. Tangelo fruit image.

2.3 Filtering

In images exist certain areas where the pixels represent abrupt intensity changes. Also, exist regions where the intensity remains constant. As a way to normalize the data contained by the pixels, in the fruit recognition task for this application, a high pass filter was used to highlight the abrupt intensity changes, in other words the edges of the fruits. Figure 3 shows the filtering process used to detect a Citrus x Tangelo contour.

The highlight process of the contours of the images is achieved using a Gaussian filter, as the one presented in Equation 2.

$$G(x,y) = e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (2)$$

Where,

x, y = Spatial coordinates.

σ = Standard deviation orcoverage rate (for this case, is equal to 15).

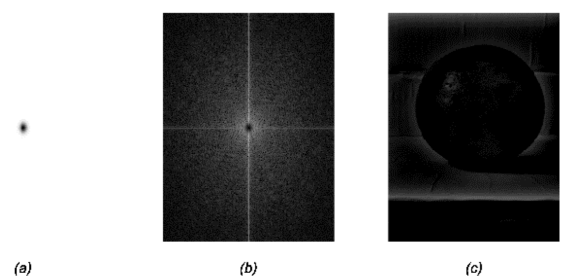

Figure 3. (a) High-pass Gaussian filter, (b) Spectra and filter multiplication, (c) Resulted image of the filtering process.

2.4 Circle Hough Transform

The circle Hough transforms is an extraction method to detect circular contours present in an image. The CHT is a variation of the original Hough transforms[13] and aims to detect circumferences in a plane searching for aligned points that met the equation of a circle. Equation 3 represents a circle´s equation.

$$(x-a)^2 + (y-b)^2 = r^2 \quad (3)$$

The steps for the CHT calculation are explained below.

2.5 Accumulator Vector Calculation

The accumulator vector stores the points that could meet the circumference equation criteria. Those points increase their magnitude through a vote system, where the probability calculation of a possible center point of a circle determines the magnitude variation.

2.5 Center Estimation

Once the accumulator vector is filled, the local maximum data are assumed as centers of circumferences. Then the spatial coordinates (x, y) of the pixels, are stored to posterior processing stages.

3. Radius Estimation

The radius estimation is performed through the minimum and maximum data registered in the accumulator vector. When a center candidate is found, then is proceeded to estimate the points that satisfy equation 3 within the possible ranges.

Figure 4 shows an example of a circular contour detection for a Citrus x Tangelo image. The filtered spectrum data of the image is used as basis for the CHT calculation, which highlights the image details and reduces computational costs of the algorithm to feasibly estimate the contour. In[14], are shown similar results related to fruit segmentation.

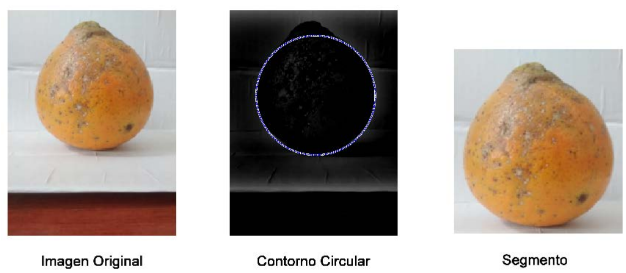

Figure 4. Circular Hough transform for detecting circular contour.

3.1 HSB Color Model

The HSB is a mathematical model which is used to represent the colors based on three parameters: Hue, Saturation and Brightness[15] such as objects or buildings. Detection of such objects is based on the detection of locally bright pixels, followed by clustering of neighborhoods of pixels. Synthetic Aperture Radar (SAR.

The Hue of an image is obtained using the conventional RGB representation applying Equation 4. The application of (4) reduces the three-component color space to a circle representation whose degree divisions correspond to the

RGB combinations. The red color is located at 0°, green at 120° and Blue at 240°. This representations allows to reduce a three dimensional problem to an angle value.

$$[\tan(H]_{rgb}) = \frac{\sqrt{3} * (G - B)}{2 * R - G - B} \quad (4)$$

Saturation is the measured distance from the circle contour, to the center and represents the tonality color loss. Equation (5) shows the saturation calculation.

$$S_{rgb} = 1 - \frac{MIN(R,G,B)}{MAX(R,G,B)} \quad (5)$$

In the Equation (6) is defined the Brightness of the color in function of the hue and saturation. Brightness represents the amount of white or black color in the image, and is calculated as the mean of the three colors.

$$B_{rgb} = \frac{R + G + B}{3} \quad (6)$$

Figure 5 shows the HSB conversion from an RGB representation of a Citrus x Tangelo which is affected by *A. aurantii.*

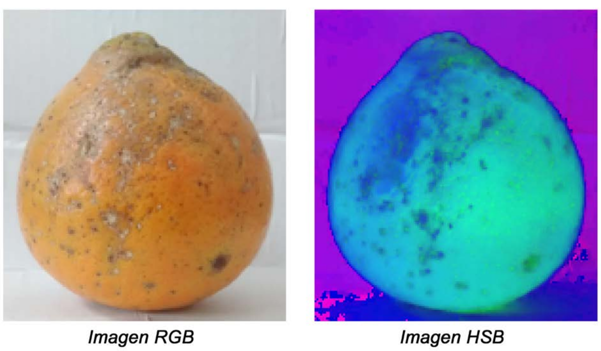

Figure 5. HSB conversion from RGB representation.

4. Results

The implementation of the Gaussian filter and the CHT allowed building an algorithm capable to identify and classify Citrus x Tangelo fruits, using as parameter the recognized affected surface. In addition to the shape estimation and the intensity filtering of the images, color masks are used from the histogram representation from the HSB color model. Figure 6 depicts the histogram taken from the hue parameter of a tangelo image.

Figure 7 shows the result of the implementation of the color mask which is used to select the fruit area, in order to obtain the binarization and the area calculation.

After the image segmentation, a new mask is applied to recognize the free - *A. auranti* area of the fruit. Figure 8 shows the histogram after the application of the second color mask.

Using the second histogram information is possible to obtain the healthy area of the fruit as shown in Figure 9.

As the system is integrated by two cameras, the process of estimation of the percentage of healthy area in the fruit is repeated for each of the sides captured in the images. This process is depicted in Figure 10.

As a last main step, the Equation (7) is applied to calculate the exact healthy area of the fruit.

$$\%\, A.Health = 0.5 * \%A.Side\,1 + 0.5 * \%A.Side\,2 \quad (7)$$

From the calculated data showed in Figure10, the total healthy area percentage applying (7), is:

$$\%A.Health = 0.5 * 67.954\% + 0.5 * 94.623\%$$

$$\%A.Health = 81.28\%$$

The threshold function defined in (8), shows the logic states of activation of the pneumatic actuator, in order to deny or allow the pass of a certain fruit.

$$f(\%A.Health) = \begin{cases} 1 & A.Health \geq 90\% \\ 0 & A.Health \leq 89\% \end{cases} \quad (8)$$

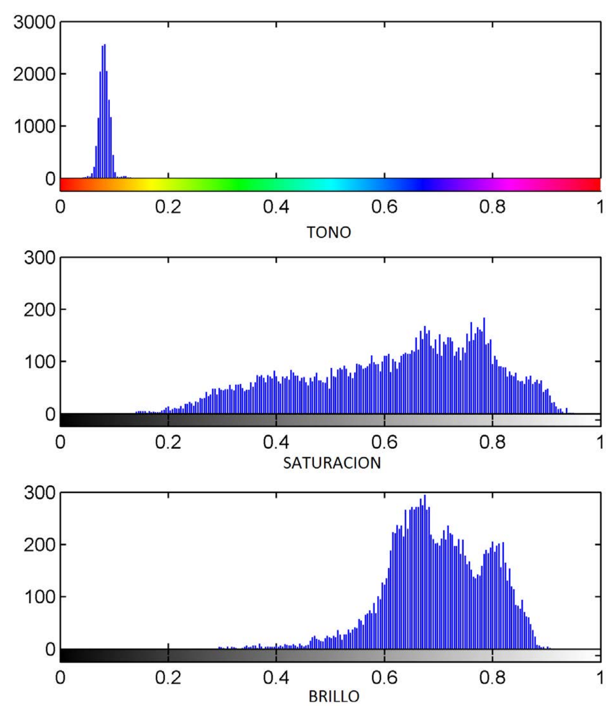

Figure 6. Histogram of the HSB space for the image Hue.

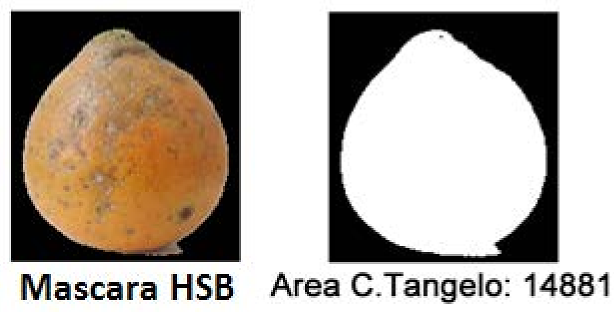

Figure 7. Color mask applied to extract the fruit to analyze.

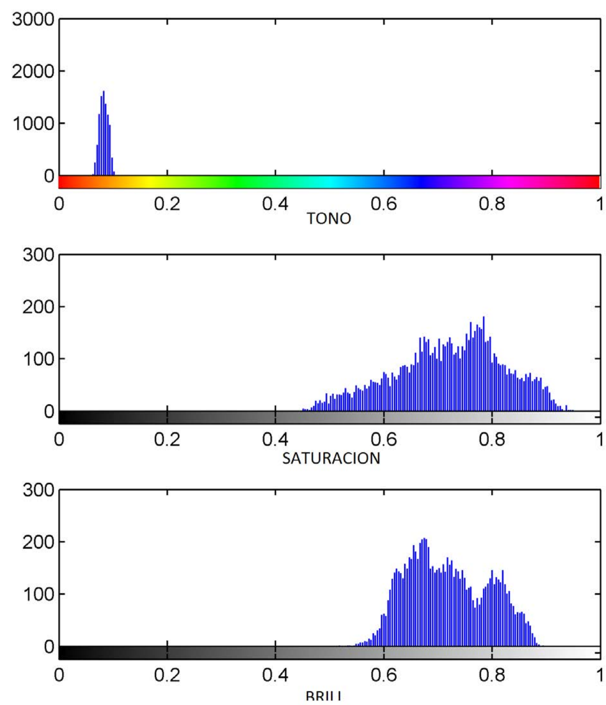

Figure 8. HSB histogram after the second mask application.

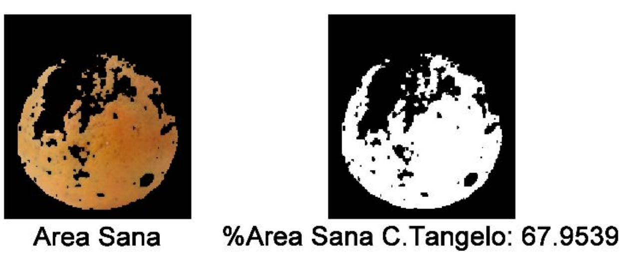

Figure 9. Healthy area of the fruit.

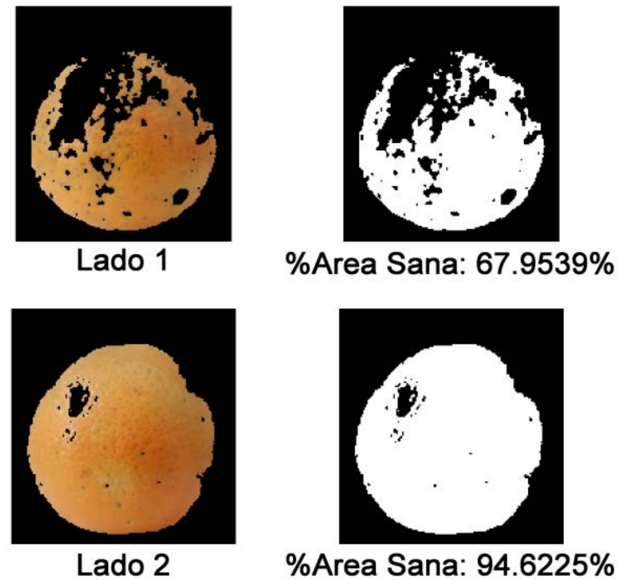

Figure 10. Healthy area estimation for each of the sides of one Citrus x Tangelo fruit.

5. Conclusions

The technological approaches in order to improve the methodologies for agricultural production could be a point of transformation to locate this kind of activities in a competitive level, reducing costs and time productions, providing tools for the agriculturist to compete in the industrialized commerce.

One of the factors to obtain a feasible identification of the health areas on the fruits was the quantity and quality of light in the work environment, which a degradation of these factors could lead to a bad interpretation of the data when reflections or shadows are present. In this case, light conditions were adjusted to guarantee the recognition.

As a future goal in order to extend this work and the results, is intended to apply artificial intelligence methods to classify and identify pests in surface areas taking into account, color, fruit maturity, ripening, shapes and size of the fruits.

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